

# Relativistic Binary Merging Rate in the Universe: 25 years of confrontation

V.M.Lipunov<sup>1</sup>

<sup>1</sup> - Sternberg Astronomical Institute, Moscow, 119899, Russia

lipunov@sai.msu.ru

Recently estimation of merger rate of double neutron stars from the observations of PSR J0737-3039 by [Burgay et.al.,2003] is discussed under real astrophysical background.

KEYWORDS Stars: evolution – Stars: neutron – binaries: general

## Introduction

Relativistic stars (neutron stars and black holes) merging can be discussed like "astrophysics" reaction of "elementary particle" interaction. This merging is analogous to elementary physics processes in the world of elementary particles ([Lipunov,1993]). There is no doubt, that there are the following processes in the Universe:

NS + NS

$\Rightarrow$

BH + GWB

The result depends on the mass of neutron star and Oppenheimer-Volkoff limit.

NS + BH  $\Rightarrow$  BH + GWB

BH + BH  $\Rightarrow$  BH + GWB,

where GWB is the Gravitational Wave Burst.

The "cross-section" or probability calculation of these processes in the Universe is of principal importance not only for astrophysics, but, first, for fundamental physics, so as exactly these processes are accompanied by the most powerful gravitational-wave emission. This emission has an impulse character, which can be detected by gravitationally-waved antenna like LIGO.

The powerful of gravitation wave emission in these processes approximate to maximum possible value in nature (even if we take into account the future theory of quantum gravitation ([Lipunov,1993]):

$$L_{max} = M_c^2/R_g c = E_{pl}/t_{pl} = C^5/G = 10^{58} \text{ erg/s} \quad (1)$$

The detection of such processes possibility has been done by only 2 ways last 20 years. First one is to use our understanding of binary stars evolution processes and to use observed astronomical data in all wave-lengths. Second one is based upon radio-astronomical data by radio-pulsars. Let's consider them.

## Two methods of merging rate estimations.

Both methods are based upon the observed data of Our Galaxy with the following generalization to the whole Universe. But historically first one is called by "theoretical", and the second one is called by "observed". It's not right as a matter of fact, but let's use this terminology.

The possibility of the processes or the cross-section can be characterized in the terms of "merging rate", normalized to the galaxy like Our one. Practically, normalization on  $10^{11}M_{\odot}$  of luminous barionic matter is suggested.

"Theoretical" estimation is always attached to the following chain:

- *Merging Rate is equal to Star Formation Rate in galaxy (Solpiter Function);*
- *the part of binary stars, that can form the relativistic star (the distribution function by the relation of masses of binary components);*
- *the part of the stars, that survived after the first Super-Nova explosion (it's strongly depends on the anisotropy of the collapse or so called kick-velocity);*
- *the part of neutron stars after the second explosion and*
- *the part of double relativistic stars, that can be merged at the Hubble time.*

The most weak link in this chain is our unknowledge of possibility of collapse anisotropy. But the "theoretical" method, that was realized in the most completely realization (see monograph "Scenario Machine", Lipunov et al., 1996, Tutukov et al.), suggests the obligatory calibration of unknown parameters by the observed data in all wave-length (from radio to x-ray). So, if the mean output velocity would be too large, all massive x-ray stars like x-ray-pulsars would be disappear from the sky (Cen X-3, Vela X-1, etc., the number is about 50), so as at large anisotropy of the collapse the binary stars will be too quickly broken. On the contrary there will be too much of such systems at small anisotropy, and there will be contradiction with observed number of binary radio-pulsars. The first method ([Lipunov et al., 1987]) gave the estimation in  $10^{-4}$  on the galaxy like Our one. (see Fig. 1)

Second "observed" method was first used by [Phinney, 1991]. It based on observed parameters of binary radio-pulsars, that can be merged at the Hubble time. At the 1991 there was only one such pulsars, and the estimation was  $10^{-6}year^{-1}$  in our Galaxy ( $10^{10}M_{\odot}$ ).

Just this not right estimation, to our mind, served to begin the building the gravity interferometer LIGO.

The main problem of observed method is not in the fact, that there was used only one observed example for statistical estimation, and is not in the fact, that interpretation of observations always was difficult from the selection effects (uncertainty of the distance, collimation angle, life-time, horizon of sensitivity that is much more smaller, than Galaxy; we see less than 1% of all radio-pulsars). The main problem is in the interest to the process of neutron stars merging, no radio-pulsars. Simple analyse shows, that neutron star passes not less than 6 physically different states during its rotating evolution. The phenomena of radio-pulsars is very specific from these states, and in not always able to be observed ([Lipunov, 1991])

There are the change of the probability estimation of the process of neutron stars merging during the last 25 years in the Table and Graphic (Fig.2). One can compare them. I assert, that most adequate to modern standard of interpretation of binary and relativistic stars evolution "theoretical" estimation didn't change during the last 17 years and beginning from the 1987 year always gave the

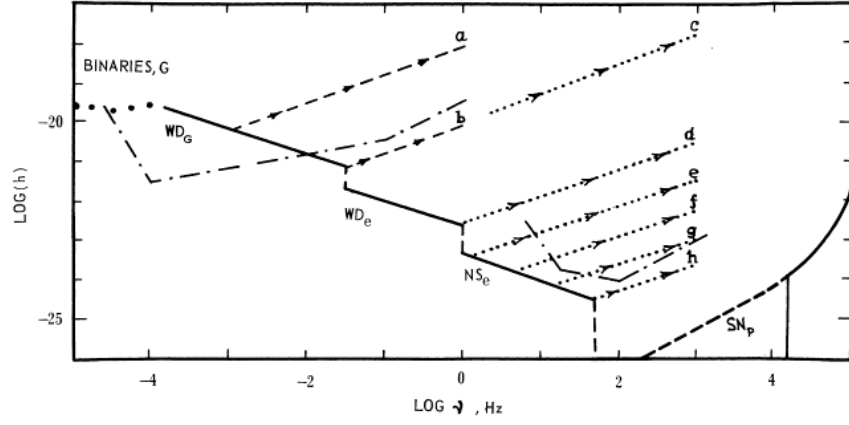


Figure 1: Gravitational Wave Spectra from astrophysical sources ([Lipunov et al., 1987]). NS merging rate ( $year^{-1}$ ) for distances less than 20 Mpc (line e). It corresponds to Merging Rate in  $1/10^4$  yrs per  $10^{11}$  solar Mass.

value  $10^{-4\pm0.5}/year$  in the levels of reduced precision.

This estimation corresponds to one merging per minute in whole Universe and to 1 event per year at the gravity-waved detector with  $10^{-21}$  sensitivity.

Table 1: "Theoretical" estimations of Neutron Stars Merging normalized to  $10^{11}M_{\odot}$  .

Author	Estimation
[Clark et al., 1979]	$1/10^4 - 1/10^6$
[Lipunov et al., 1987]	$1/10^4$
[Hills et al., 1990]	$1/10^4$
[Tutukov, Yungelson, 1993]	$1/10^4$
[Lipunov et al., 1995]	$< 3/10^4$
[Portegies, Spreeuw, 1996]	$3/10^5$
[Lipunov et al., 1996]	$3/10^4 - 3/10^5$
[Portegies, Yungelson, 1998]	$1/10^4 - 3/10^5$
[Bethe, Brown, 1999]	$1/10^4$

Table 2: "Observed" estimations of Neutron Stars Merging Rate.

Author	Estimation
[Phinney, 1991]	$1/10^6$
[Narayan et al., 1991]	$1/10^6$
[Curran, Lorimer, 1995]	$3/10^6$
[Van den Heuvel, Lorimer, 1996]	$8/10^6$
[Bailes, 1996]	$< 1/10^5$
[Burgay et.al., 2003]	$1/10^4$

More difficult problem is to estimate the frequency of the reaction with black hole participation. Our understanding of the evolution is essentially worse here. Nevertheless, [Lipunov et al., 1997b], [Lipunov et al., 1997c] could get round the theoretical uncertainty, using simple observed limits. They are the following: there is no any radiopulsar with black hole on the sky (this is up limit) and there is at least several black holes in the binary with massive optical stars (for ex., Cyg X-1) in Our Galaxy. As it was shown in [Lipunov et al., 1997b], [Lipunov et al., 1997c], it is more possible to register the gravity-waved impulse from the black-holes merging:

$$BH + NS \Rightarrow BH + GWB$$

$$BH + BH \Rightarrow BH + GWB \ 10^{-5}/year/galaxy$$

So as the mean black hole mass can be in 8-10 times more, the frequently of these processes at the detector can be essentially more, than from the neutron stars merging (see Fig.3).

Recently, [Lipunov, Panchenko, 2003] proved that preliminary possibility of last two processes can be increased up to 5-7 times.

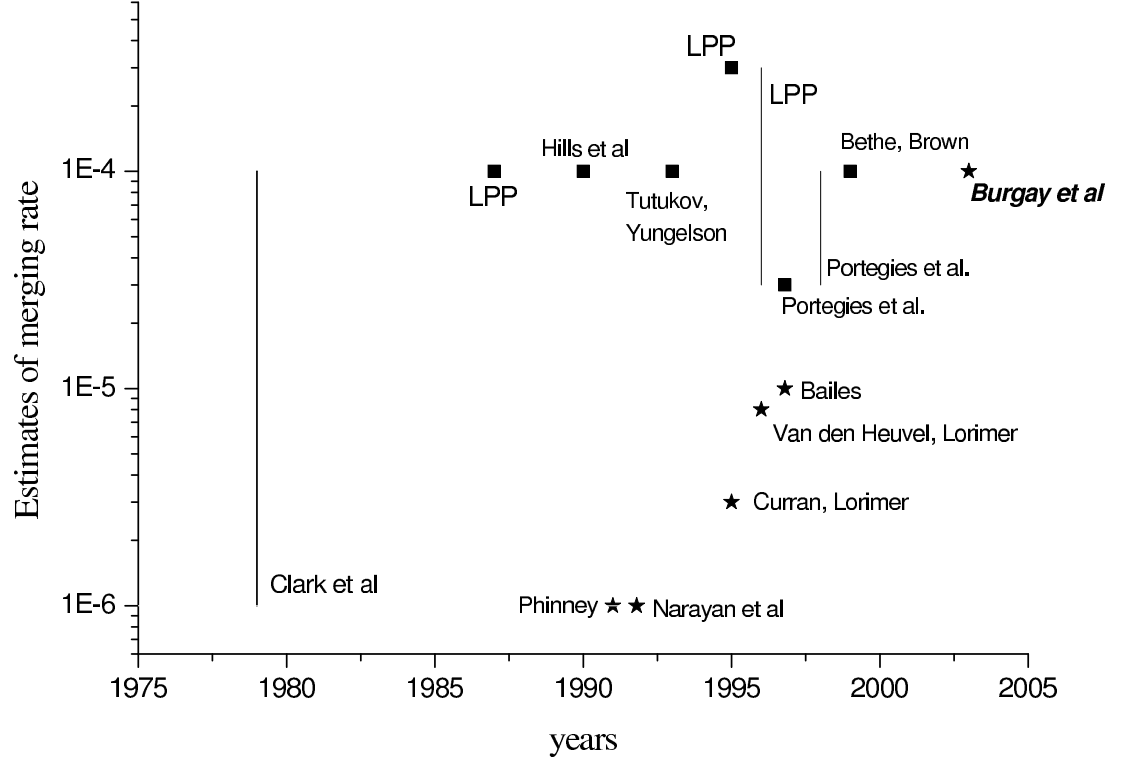


Figure 2: Merging Rate estimation by different authors. Squares are the "theoretical" method, "stars" are the observational one.

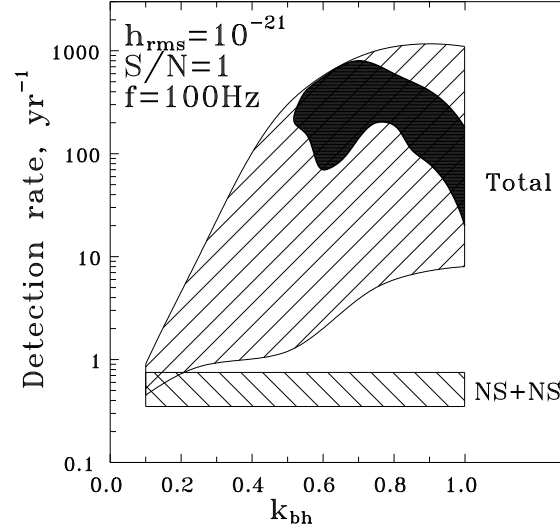


Figure 3: Predicted Detector rates for **Neutron Stars** (horizontal branch) and **Neutron Stars - Black Holes** and **BH + BH** - dark area ([Lipunov et al., 1997b]).  $K_{bh}$  is the part of pre-supernova mass which collapsed into the Black Hole.

## Conclusions

1) So called "theoretical" estimations give us the merging rate for Neutron Stars in  $10^{-4\pm0.5}$  from [Lipunov et al., 1987]. I accent, that "theoretical" estimation isn't simple average between the results of different authors. All articles, that gives the merging rate for NS+NS less than  $1/(3 * 10^4) year^{-1}$  are wrong, becouse in this case all binary radiopulsars and binary X-ray pulsars disappear from the sky [Lipunov et al., 1997a]. There are another points of view (for ex., [Kalogera, Lorimer, 2000]), I can't agree with them. One must accentuate, that the most full and correct model of binary stars evolution is the "Scenario Machine", that takes into account the evolution of magnetized neutron star (see for details [Lipunov et al., 1996])

2) The "observed" estimations, that used radio-pulsars data, were always burdened by selection effects.

3) The gravitation impulses from the merging with black holes participation must be the first events on the interferometers like LIGO ([Lipunov et al.,1997b],[Lipunov et al.,1997c]).

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